

**$\Delta(1700)$   $D_{33}$**  $I(J^P) = \frac{3}{2}(\frac{3}{2}^-)$  Status: \*\*\*

Most of the results published before 1975 were last included in our 1982 edition, Physics Letters **111B** 1 (1982). Some further obsolete results published before 1980 were last included in our 2006 edition, Journal of Physics, G **33** 1 (2006).

 **$\Delta(1700)$  BREIT-WIGNER MASS**

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>1670 to 1750 (<math>\approx 1700</math>) OUR ESTIMATE</b>			
1695.0 $\pm$ 1.3	ARNDT 06	DPWA	$\pi N \rightarrow \pi N, \eta N$
1762 $\pm$ 44	MANLEY 92	IPWA	$\pi N \rightarrow \pi N & N\pi\pi$
1710 $\pm$ 30	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
1680 $\pm$ 70	HOEHLER 79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1687.9 $\pm$ 2.5	ARNDT 04	DPWA	$\pi N \rightarrow \pi N, \eta N$
1678 $\pm$ 1	PENNER 02C	DPWA	Multichannel
1732 $\pm$ 23	VRANA 00	DPWA	Multichannel
1690 $\pm$ 15	ARNDT 96	IPWA	$\gamma N \rightarrow \pi N$
1680	ARNDT 95	DPWA	$\pi N \rightarrow N\pi$
1655	LI 93	IPWA	$\gamma N \rightarrow \pi N$
1650	BARNHAM 80	IPWA	$\pi N \rightarrow N\pi\pi$
1718.4 $^{+13.1}_{-13.0}$	<sup>1</sup> CHEW 80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1622	CRAWFORD 80	DPWA	$\gamma N \rightarrow \pi N$
1600	<sup>2</sup> LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$
1680	<sup>3</sup> LONGACRE 75	IPWA	$\pi N \rightarrow N\pi\pi$

 **$\Delta(1700)$  BREIT-WIGNER WIDTH**

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>200 to 400 (<math>\approx 300</math>) OUR ESTIMATE</b>			
375.5 $\pm$ 7.0	ARNDT 06	DPWA	$\pi N \rightarrow \pi N, \eta N$
600 $\pm$ 250	MANLEY 92	IPWA	$\pi N \rightarrow \pi N & N\pi\pi$
280 $\pm$ 80	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
230 $\pm$ 80	HOEHLER 79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
364.8 $\pm$ 16.6	ARNDT 04	DPWA	$\pi N \rightarrow \pi N, \eta N$
606 $\pm$ 15	PENNER 02C	DPWA	Multichannel
119 $\pm$ 70	VRANA 00	DPWA	Multichannel
285 $\pm$ 20	ARNDT 96	IPWA	$\gamma N \rightarrow \pi N$
272	ARNDT 95	DPWA	$\pi N \rightarrow N\pi$
348	LI 93	IPWA	$\gamma N \rightarrow \pi N$
160	BARNHAM 80	IPWA	$\pi N \rightarrow N\pi\pi$
193.3 $\pm$ 26.0	<sup>1</sup> CHEW 80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
209	CRAWFORD 80	DPWA	$\gamma N \rightarrow \pi N$
200	<sup>2</sup> LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$
240	<sup>3</sup> LONGACRE 75	IPWA	$\pi N \rightarrow N\pi\pi$

## $\Delta(1700)$ POLE POSITION

### REAL PART

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>1620 to 1680 (<math>\approx 1650</math>) OUR ESTIMATE</b>			
1632	ARNDT 06	DPWA	$\pi N \rightarrow \pi N, \eta N$
1651	4 HOEHLER 93	SPED	$\pi N \rightarrow \pi N$
$1675 \pm 25$	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
<b>• • • We do not use the following data for averages, fits, limits, etc. • • •</b>			
1617	ARNDT 04	DPWA	$\pi N \rightarrow \pi N, \eta N$
1726	VRANA 00	DPWA	Multichannel
1655	ARNDT 95	DPWA	$\pi N \rightarrow N\pi$
1646	ARNDT 91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1681 or 1672	5 LONGACRE 78	IPWA	$\pi N \rightarrow N\pi\pi$
1600 or 1594	2 LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$

### -2xIMAGINARY PART

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>160 to 240 (<math>\approx 200</math>) OUR ESTIMATE</b>			
253	ARNDT 06	DPWA	$\pi N \rightarrow \pi N, \eta N$
159	4 HOEHLER 93	SPED	$\pi N \rightarrow \pi N$
$220 \pm 40$	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
<b>• • • We do not use the following data for averages, fits, limits, etc. • • •</b>			
226	ARNDT 04	DPWA	$\pi N \rightarrow \pi N, \eta N$
118	VRANA 00	DPWA	Multichannel
242	ARNDT 95	DPWA	$\pi N \rightarrow N\pi$
208	ARNDT 91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
245 or 241	5 LONGACRE 78	IPWA	$\pi N \rightarrow N\pi\pi$
208 or 201	2 LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$

## $\Delta(1700)$ ELASTIC POLE RESIDUE

### MODULUS $|r|$

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
18	ARNDT 06	DPWA	$\pi N \rightarrow \pi N, \eta N$
10	HOEHLER 93	SPED	$\pi N \rightarrow \pi N$
$13 \pm 3$	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
<b>• • • We do not use the following data for averages, fits, limits, etc. • • •</b>			
16	ARNDT 04	DPWA	$\pi N \rightarrow \pi N, \eta N$
16	ARNDT 95	DPWA	$\pi N \rightarrow N\pi$
13	ARNDT 91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

### PHASE $\theta$

<u>VALUE (°)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
-40	ARNDT 06	DPWA	$\pi N \rightarrow \pi N, \eta N$
$-20 \pm 25$	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
<b>• • • We do not use the following data for averages, fits, limits, etc. • • •</b>			
-47	ARNDT 04	DPWA	$\pi N \rightarrow \pi N, \eta N$
-12	ARNDT 95	DPWA	$\pi N \rightarrow N\pi$
-22	ARNDT 91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

## $\Delta(1700)$ DECAY MODES

The following branching fractions are our estimates, not fits or averages.

Mode	Fraction ( $\Gamma_i/\Gamma$ )
$\Gamma_1 N\pi$	10–20 %
$\Gamma_2 \Sigma K$	
$\Gamma_3 N\pi\pi$	80–90 %
$\Gamma_4 \Delta\pi$	30–60 %
$\Gamma_5 \Delta(1232)\pi$ , <i>S</i> -wave	25–50 %
$\Gamma_6 \Delta(1232)\pi$ , <i>D</i> -wave	1–7 %
$\Gamma_7 N\rho$	30–55 %
$\Gamma_8 N\rho$ , $S=1/2$ , <i>D</i> -wave	
$\Gamma_9 N\rho$ , $S=3/2$ , <i>S</i> -wave	5–20 %
$\Gamma_{10} N\rho$ , $S=3/2$ , <i>D</i> -wave	
$\Gamma_{11} N\gamma$	0.12–0.26 %
$\Gamma_{12} N\gamma$ , helicity=1/2	0.08–0.16 %
$\Gamma_{13} N\gamma$ , helicity=3/2	0.025–0.12 %

## $\Delta(1700)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$	$\Gamma_1/\Gamma$		
VALUE	DOCUMENT ID	TECN	COMMENT
<b>0.10 to 0.20 OUR ESTIMATE</b>			
0.156 ± 0.001	ARNDT 06	DPWA	$\pi N \rightarrow \pi N, \eta N$
0.14 ± 0.06	MANLEY 92	IPWA	$\pi N \rightarrow \pi N & N\pi\pi$
0.12 ± 0.03	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
0.20 ± 0.03	HOEHLER 79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.150 ± 0.001	ARNDT 04	DPWA	$\pi N \rightarrow \pi N, \eta N$
0.14 ± 0.01	PENNER 02C	DPWA	Multichannel
0.05 ± 0.01	VRANA 00	DPWA	Multichannel
0.16	ARNDT 95	DPWA	$\pi N \rightarrow N\pi$
0.16	<sup>1</sup> CHEW 80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

Note: Signs of couplings from  $\pi N \rightarrow N\pi\pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the  $\Delta(1620) S_{31}$  coupling to  $\Delta(1232)\pi$ .

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \Delta(1700) \rightarrow \Delta(1232)\pi$ , <i>S</i> -wave	$(\Gamma_1\Gamma_5)^{1/2}/\Gamma$		
VALUE	DOCUMENT ID	TECN	COMMENT
<b>+0.21 to +0.29 OUR ESTIMATE</b>			
+0.32 ± 0.06	MANLEY 92	IPWA	$\pi N \rightarrow \pi N & N\pi\pi$
+0.18 ± 0.04	BARNHAM 80	IPWA	$\pi N \rightarrow N\pi\pi$
+0.30	<sup>2,6</sup> LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$
+0.24	<sup>3</sup> LONGACRE 75	IPWA	$\pi N \rightarrow N\pi\pi$

$\Gamma(\Delta(1232)\pi, S\text{-wave})/\Gamma_{\text{total}}$

$\Gamma_5/\Gamma$

VALUE	DOCUMENT ID	TECN	COMMENT
0.90±0.02	VRANA 00	DPWA	Multichannel

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$  in  $N\pi \rightarrow \Delta(1700) \rightarrow \Delta(1232)\pi, D\text{-wave}$        $(\Gamma_1\Gamma_6)^{1/2}/\Gamma$

VALUE	DOCUMENT ID	TECN	COMMENT
<b>+0.05 to +0.11 OUR ESTIMATE</b>			
+0.08±0.03	MANLEY 92	IPWA	$\pi N \rightarrow \pi N & N\pi\pi$
0.14±0.04	BARNHAM 80	IPWA	$\pi N \rightarrow N\pi\pi$
+0.05	<sup>2,6</sup> LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$
+0.10	<sup>3</sup> LONGACRE 75	IPWA	$\pi N \rightarrow N\pi\pi$

$\Gamma(\Delta(1232)\pi, D\text{-wave})/\Gamma_{\text{total}}$

$\Gamma_6/\Gamma$

VALUE	DOCUMENT ID	TECN	COMMENT
0.04±0.01	VRANA 00	DPWA	Multichannel

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$  in  $N\pi \rightarrow \Delta(1700) \rightarrow N\rho, S=1/2, D\text{-wave}$        $(\Gamma_1\Gamma_8)^{1/2}/\Gamma$

VALUE	DOCUMENT ID	TECN	COMMENT
+0.17±0.05	BARNHAM 80	IPWA	$\pi N \rightarrow N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$  in  $N\pi \rightarrow \Delta(1700) \rightarrow N\rho, S=3/2, S\text{-wave}$        $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$

VALUE	DOCUMENT ID	TECN	COMMENT
<b>±0.11 to ±0.19 OUR ESTIMATE</b>			

+0.10±0.03	MANLEY 92	IPWA	$\pi N \rightarrow \pi N & N\pi\pi$
+0.04	<sup>2,6</sup> LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$
-0.30	<sup>3</sup> LONGACRE 75	IPWA	$\pi N \rightarrow N\pi\pi$

$\Gamma(N\rho, S=3/2, S\text{-wave})/\Gamma_{\text{total}}$

$\Gamma_9/\Gamma$

VALUE	DOCUMENT ID	TECN	COMMENT
0.01±0.01	VRANA 00	DPWA	Multichannel

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$  in  $N\pi \rightarrow \Delta(1700) \rightarrow N\rho, S=3/2, D\text{-wave}$        $(\Gamma_1\Gamma_{10})^{1/2}/\Gamma$

VALUE	DOCUMENT ID	TECN	COMMENT
0.18±0.07	BARNHAM 80	IPWA	$\pi N \rightarrow N\pi\pi$

**$\Delta(1700)$  PHOTON DECAY AMPLITUDES**

$\Delta(1700) \rightarrow N\gamma, \text{ helicity-1/2 amplitude } A_{1/2}$

VALUE (GeV <sup>-1/2</sup> )	DOCUMENT ID	TECN	COMMENT
<b>+0.104±0.015 OUR ESTIMATE</b>			

0.090±0.025	ARNDT 96	IPWA	$\gamma N \rightarrow \pi N$
0.111±0.017	CRAWFORD 83	IPWA	$\gamma N \rightarrow \pi N$
0.089±0.033	AWAJI 81	DPWA	$\gamma N \rightarrow \pi N$
0.112±0.006	ARAI 80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
0.130±0.006	ARAI 80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
0.123±0.022	CRAWFORD 80	DPWA	$\gamma N \rightarrow \pi N$

• • • We do not use the following data for averages, fits, limits, etc. • • •

0.096	PENNER 02D	DPWA	Multichannel
0.121±0.004	LI 93	IPWA	$\gamma N \rightarrow \pi N$

**$\Delta(1700) \rightarrow N\gamma$ , helicity-3/2 amplitude  $A_{3/2}$** 

VALUE ( $\text{GeV}^{-1/2}$ )	DOCUMENT ID	TECN	COMMENT
<b>+0.085±0.022 OUR ESTIMATE</b>			
0.097±0.020	ARNDT 96	IPWA	$\gamma N \rightarrow \pi N$
0.107±0.015	CRAWFORD 83	IPWA	$\gamma N \rightarrow \pi N$
0.060±0.015	AWAJI 81	DPWA	$\gamma N \rightarrow \pi N$
0.047±0.007	ARAI 80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
0.050±0.007	ARAI 80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
0.102±0.015	CRAWFORD 80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.154	PENNER 02D	DPWA	Multichannel
0.115±0.004	LI 93	IPWA	$\gamma N \rightarrow \pi N$

 **$\Delta(1700)$  FOOTNOTES**

<sup>1</sup> Problems with CHEW 80 are discussed in section 2.1.11 of HOEHLER 83.

<sup>2</sup> LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \rightarrow N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

<sup>3</sup> From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

<sup>4</sup> See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of  $N$  and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

<sup>5</sup> LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \rightarrow N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

<sup>6</sup> LONGACRE 77 considers this coupling to be well determined.

 **$\Delta(1700)$  REFERENCES**

For early references, see Physics Letters **111B** 1 (1982).

ARNDT	06	PR C74 045205	R.A. Arndt <i>et al.</i>	(GWU)
PDG	06	JPG 33 1	W.-M. Yao <i>et al.</i>	(PDG Collab.)
ARNDT	04	PR C69 035213	R.A. Arndt <i>et al.</i>	(GWU, TRIU)
PENNER	02C	PR C66 055211	G. Penner, U. Mosel	(GIES)
PENNER	02D	PR C66 055212	G. Penner, U. Mosel	(GIES)
VRANA	00	PRPL 328 181	T.P. Vrana, S.A. Dytman,, T.-S.H. Lee	(PITT+)
ARNDT	96	PR C53 430	R.A. Arndt, I.I. Strakovsky, R.L. Workman	(VPI)
ARNDT	95	PR C52 2120	R.A. Arndt <i>et al.</i>	(VPI, BRCO)
HOEHLER	93	$\pi N$ Newsletter 9 1	G. Hohler	(KARL)
LI	93	PR C47 2759	Z.J. Li <i>et al.</i>	(VPI)
MANLEY	92	PR D45 4002	D.M. Manley, E.M. Saleski	(KENT) IJP
Also		PR D30 904	D.M. Manley <i>et al.</i>	(VPI)
ARNDT	91	PR D43 2131	R.A. Arndt <i>et al.</i>	(VPI, TELE) IJP
CRAWFORD	83	NP B211 1	R.L. Crawford, W.T. Morton	(GLAS)
HOEHLER	83	Landolt-Bornstein 1/9B2	G. Hohler	(KARLT)
PDG	82	PL 111B 1	M. Roos <i>et al.</i>	(HELS, CIT, CERN)
AWAJI	81	Bonn Conf. 352	N. Awaji, R. Kajikawa	(NAGO)
Also		NP B197 365	K. Fujii <i>et al.</i>	(NAGO)
ARAI	80	Toronto Conf. 93	I. Arai	(INUS)
Also		NP B194 251	I. Arai, H. Fujii	(INUS)
BARNHAM	80	NP B168 243	K.W.J. Barnham <i>et al.</i>	(LOIC)

CHEW	80	Toronto Conf. 123	D.M. Chew	(LBL) IJP
CRAWFORD	80	Toronto Conf. 107	R.L. Crawford	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	R.E. Cutkosky <i>et al.</i>	(CMU, LBL) IJP
Also		PR D20 2839	R.E. Cutkosky <i>et al.</i>	(CMU, LBL) IJP
HOEHLER	79	PDAT 12-1	G. Hohler <i>et al.</i>	(KARLT) IJP
Also		Toronto Conf. 3	R. Koch	(KARLT) IJP
LONGACRE	78	PR D17 1795	R.S. Longacre <i>et al.</i>	(LBL, SLAC)
LONGACRE	77	NP B122 493	R.S. Longacre, J. Dolbeau	(SACL) IJP
Also		NP B108 365	J. Dolbeau <i>et al.</i>	(SACL) IJP
LONGACRE	75	PL 55B 415	R.S. Longacre <i>et al.</i>	(LBL, SLAC) IJP